Carbon Farming Workshop

David M. Babson, Ph.D., Program Director
Advanced Research Projects Agency-Energy (ARPA-E)

June 28-29, 2022 | Kansas City, MO

The ARPA-E Team for this meeting

Doug Wicks

James Zahler

Marina Sofos

Laura Demetrion

Dave Lee

Calden Stimpson

Nick Goeser

Kirk Liu

Leonela Carriedo

Daniel Garcia

<u>Not pictured</u>
Ethan Woods
Grant Opperman
Tim Gerald

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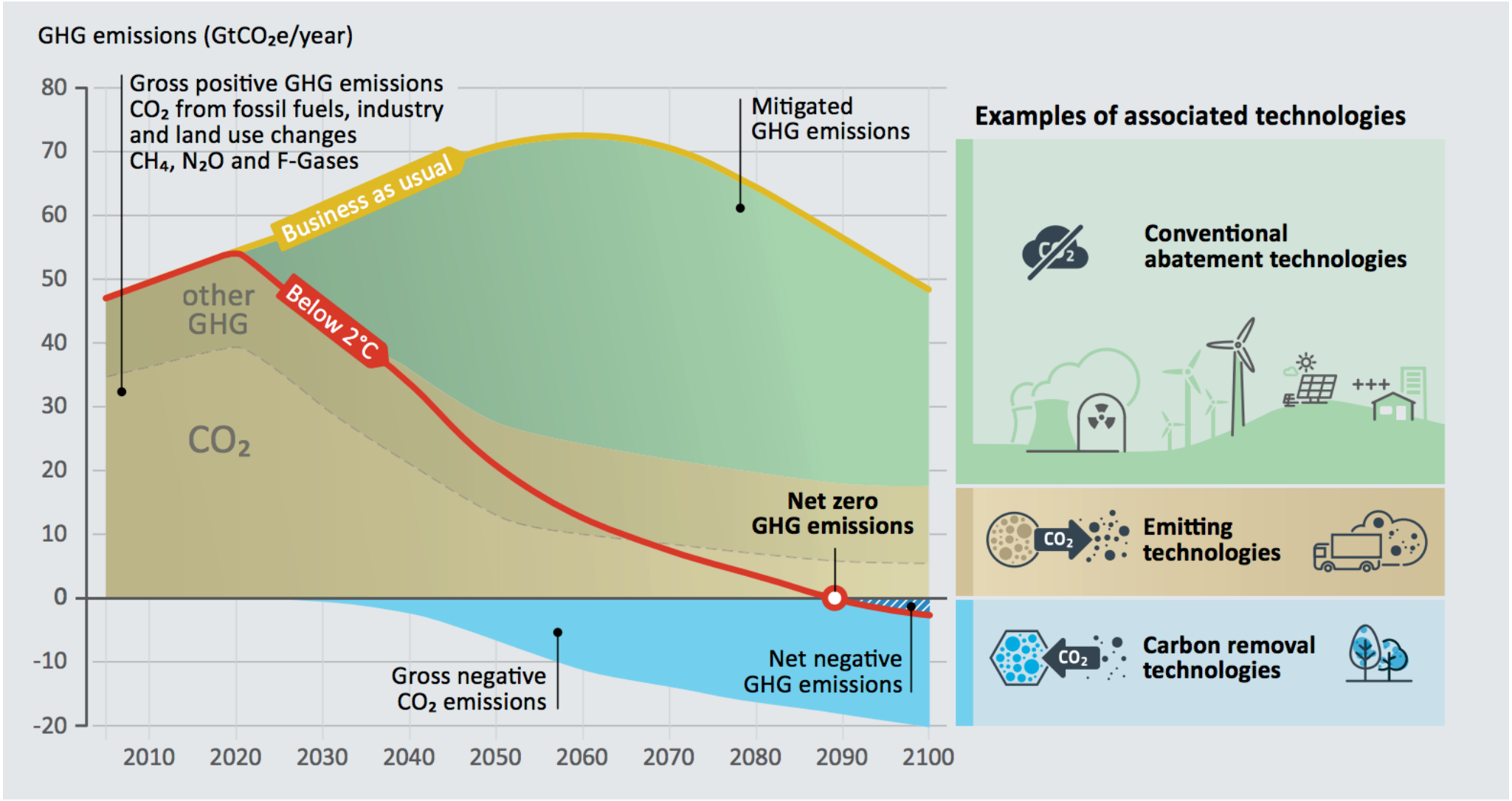
All paths to 2° C go through zero



National Academy of Sciences. *Negative Emissions Technologies and Reliable Sequestration: A Research Agenda.* 2019. p. 3

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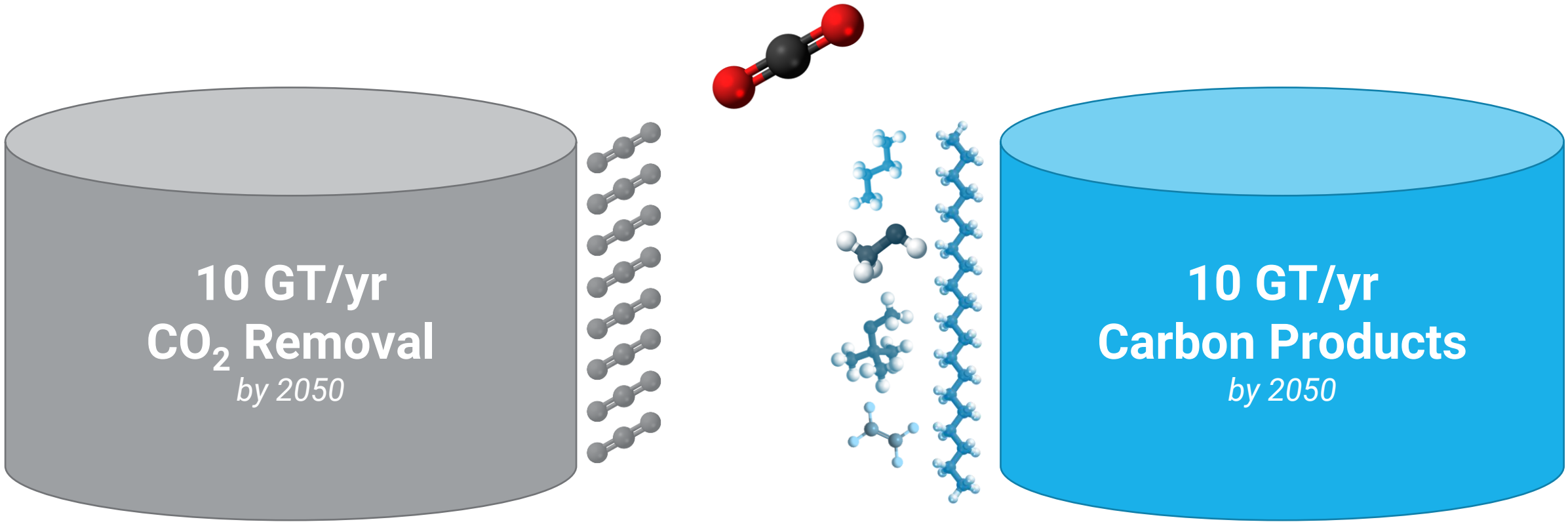
There are two *new carbon* buckets that need to be filled

Where *new carbon* is sourced, where it is directed, or how it is used matters a lot.



Low energy ***High energy***

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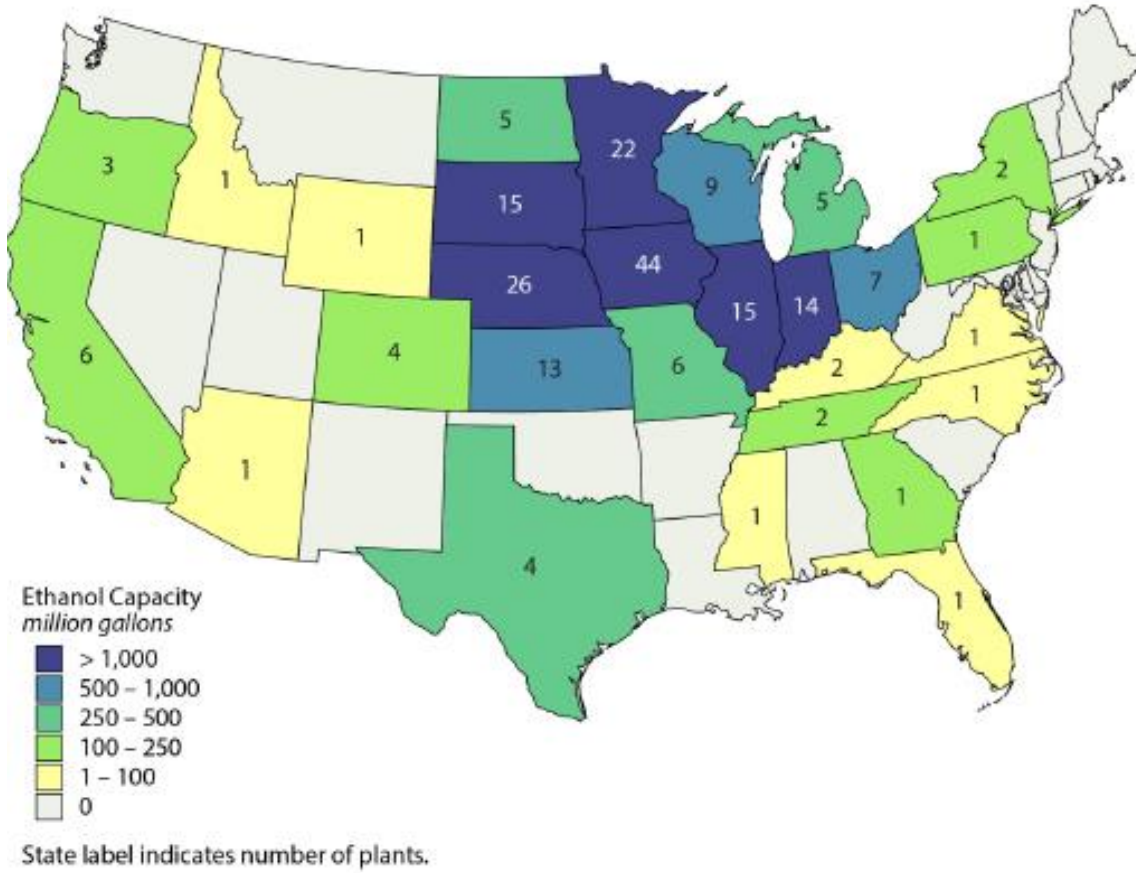
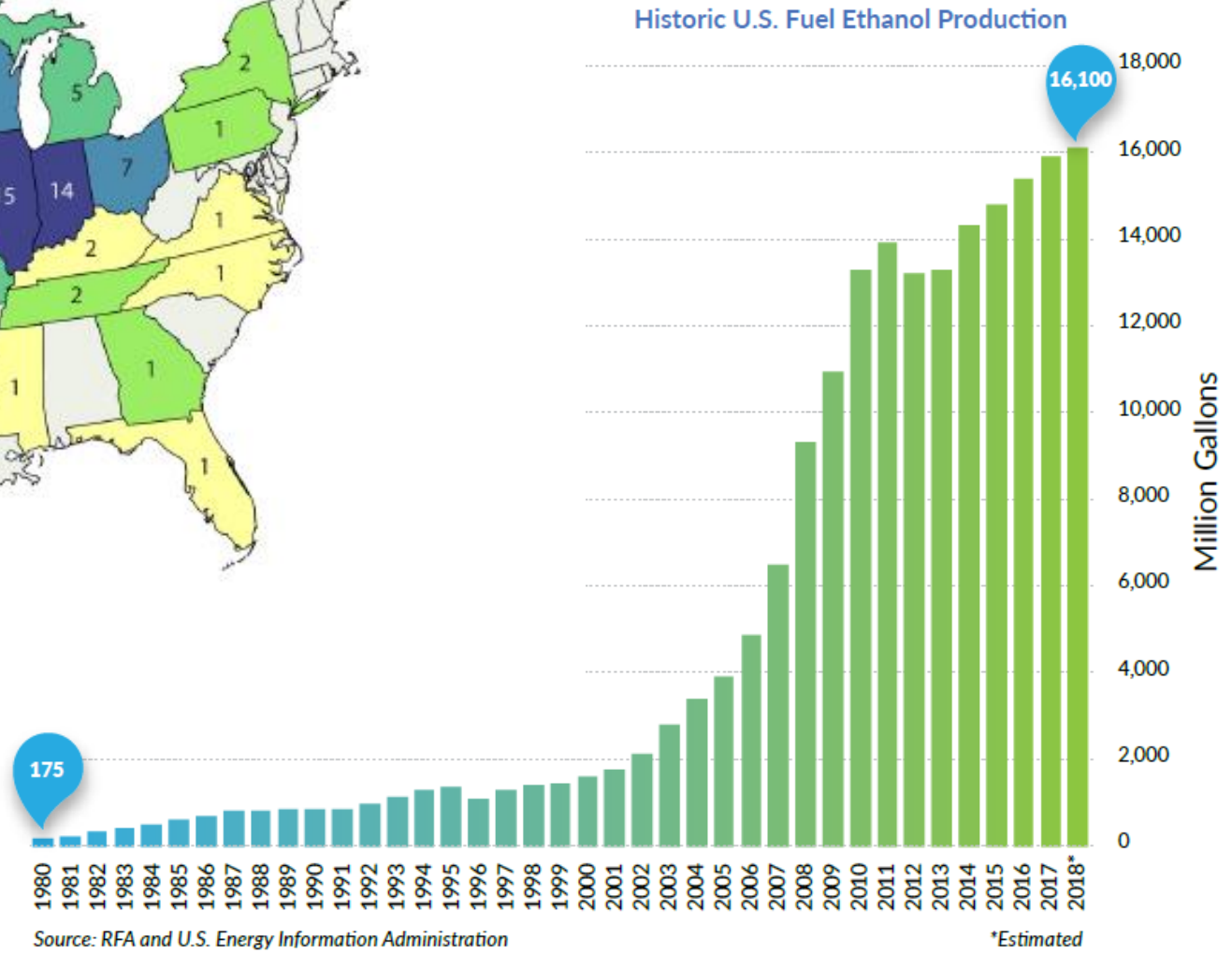
Current bioeconomy = ethanol bioeconomy

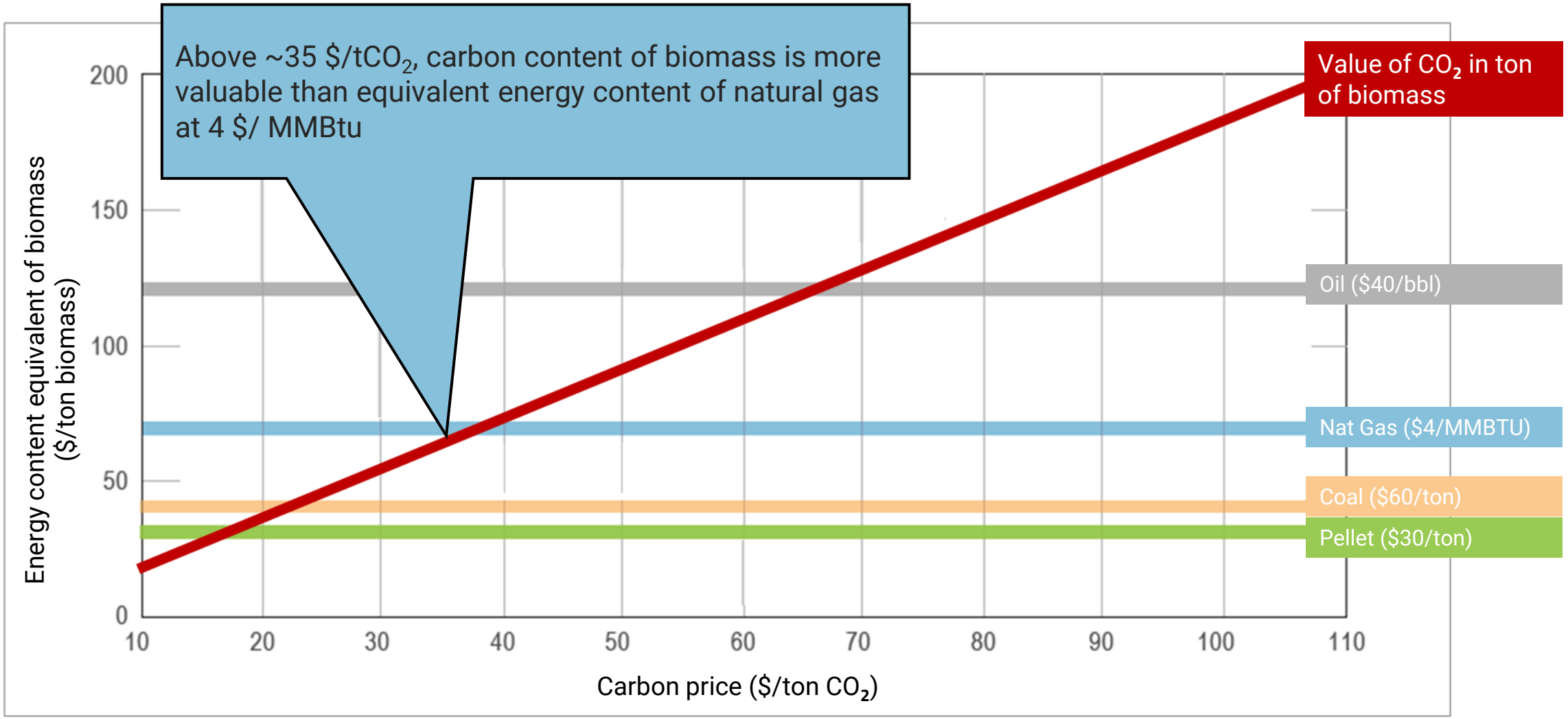




https://ethanolrfa.org/wp-content/uploads/2019/02/RFA2019Outlook.pdf

Carbon pricing redefines biomass from “energy crop” to “carbon removal crop"

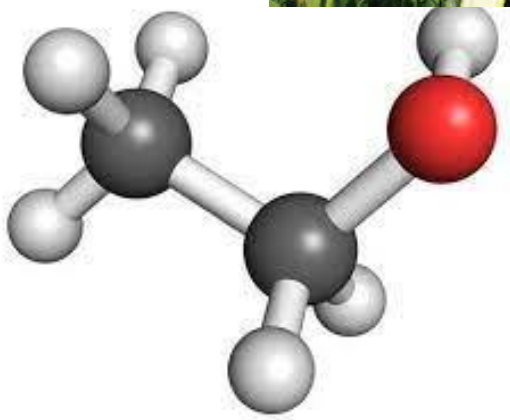
Illustrative optimal uses of biomass for energy content vs carbon removal at different carbon prices



Are we thinking about the bioeconomy the wrong way?

Bioenergy Bioeconomy

A bioeconomy that optimizes for energy product recovery and offers carbon reductions by displacing petroleum



Drawdown Bioeconomy

A bioeconomy that optimizes for carbon drawdown and offers energy reductions by displacing DAC

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Drivers for innovation – Negative Carbon *and* Negative Land Use

Carbon / GHG Emissions Reductions

Land Sparing

Our global economy needs to be structured in a way that incentivizes not only land and carbon 'neutrality', but promotes becoming both carbon and land negative.

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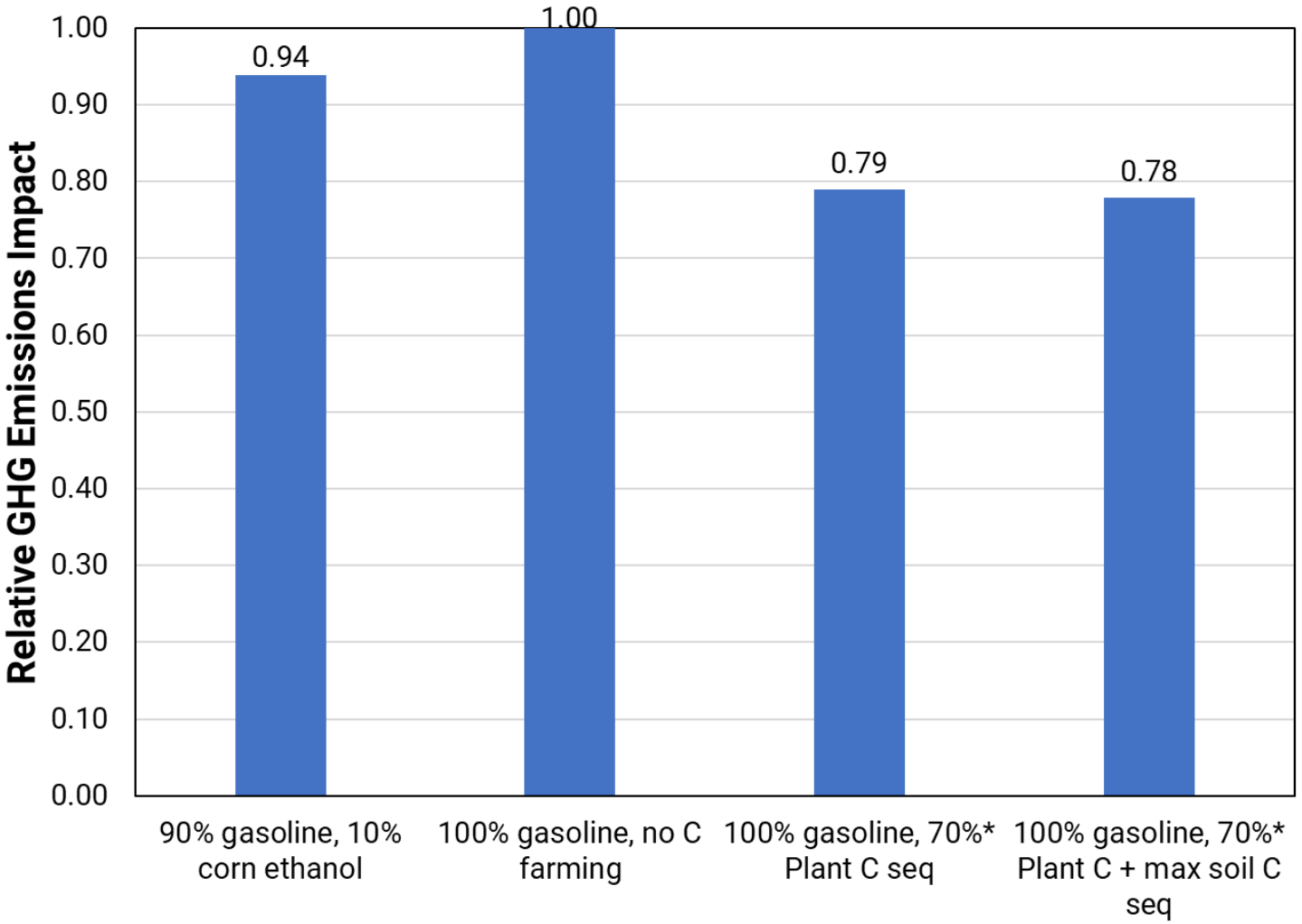
Land for today's bioethanol is better used for C drawdown



**70% C net sequestered based on burying non-hydrotreated miscanthus py-oil*

Even if bioethanol was **100% replaced with petroleum gasoline**, carbon farming is a better way to reduce overall emissions **today**

Upstream carbon removal pathways are essential to enabling a transition to a C drawdown bioeconomy

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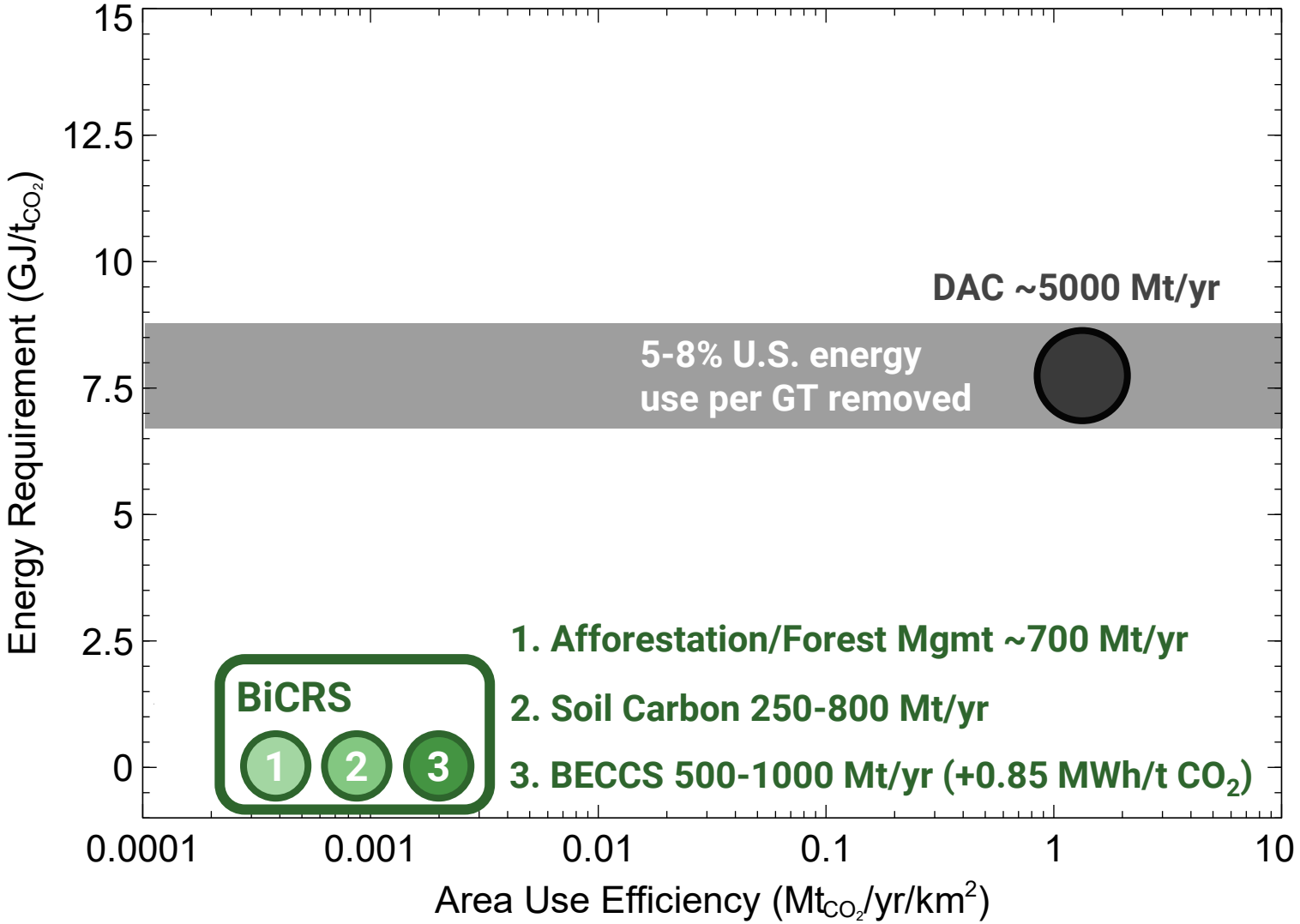
CO_2 removal via biomass alleviates CDR energy demand

...while delivering sustainable feedstocks for food, feed, fiber, and energy



Biomass Carbon Removal & Storage (BiCRS)

- Uses biomass to remove CO_2 from the atmosphere
- Stores that CO_2 underground or in long-lived products
- Does no damage to—and ideally promotes—food security, rural livelihoods, biodiversity conservation and other important values

>1 GT/yr removal @ <$50/t

Efficient, scalable BiCRS pathways start with feedstock production

Parallel Pathways:

Modify today's fuel, food, and fiber crops to promote carbon-neutral or carbon-negative ag

Exclusive Pathways

Design and optimize crops and management strategies for robust BiCRS supply chains

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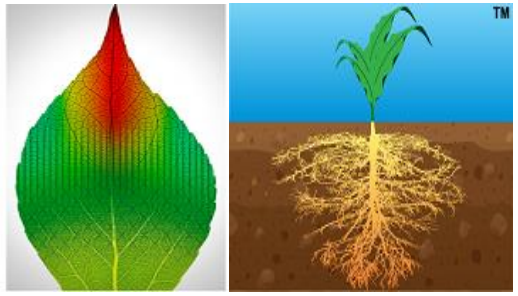
ARPA-E programs enable innovation in terrestrial biomass

Established ARPA-E Programs

TERRA / ROOTS



SMARTFARM

SMART FARM

Identify Improvements

Identify genetics for enhanced crop characteristics, deeper more robust roots

Measure Outcomes

Supply-chain-wide lifecycle accounting to measure the "carbon harvest"

"Carbon Farming"

Implement Systems

Develop new crops, soil amendments, management strategies, and market enablers for carbon-negative land management systems

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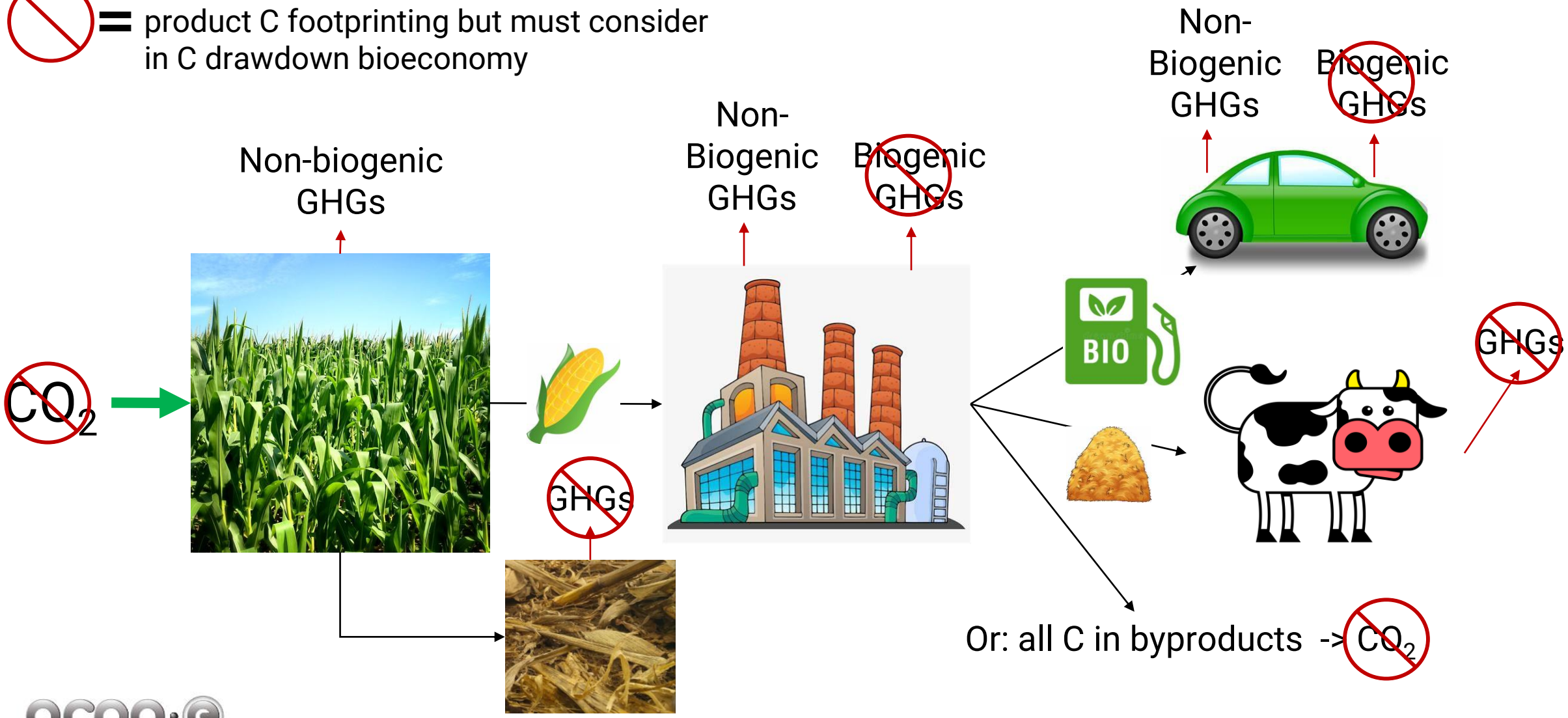
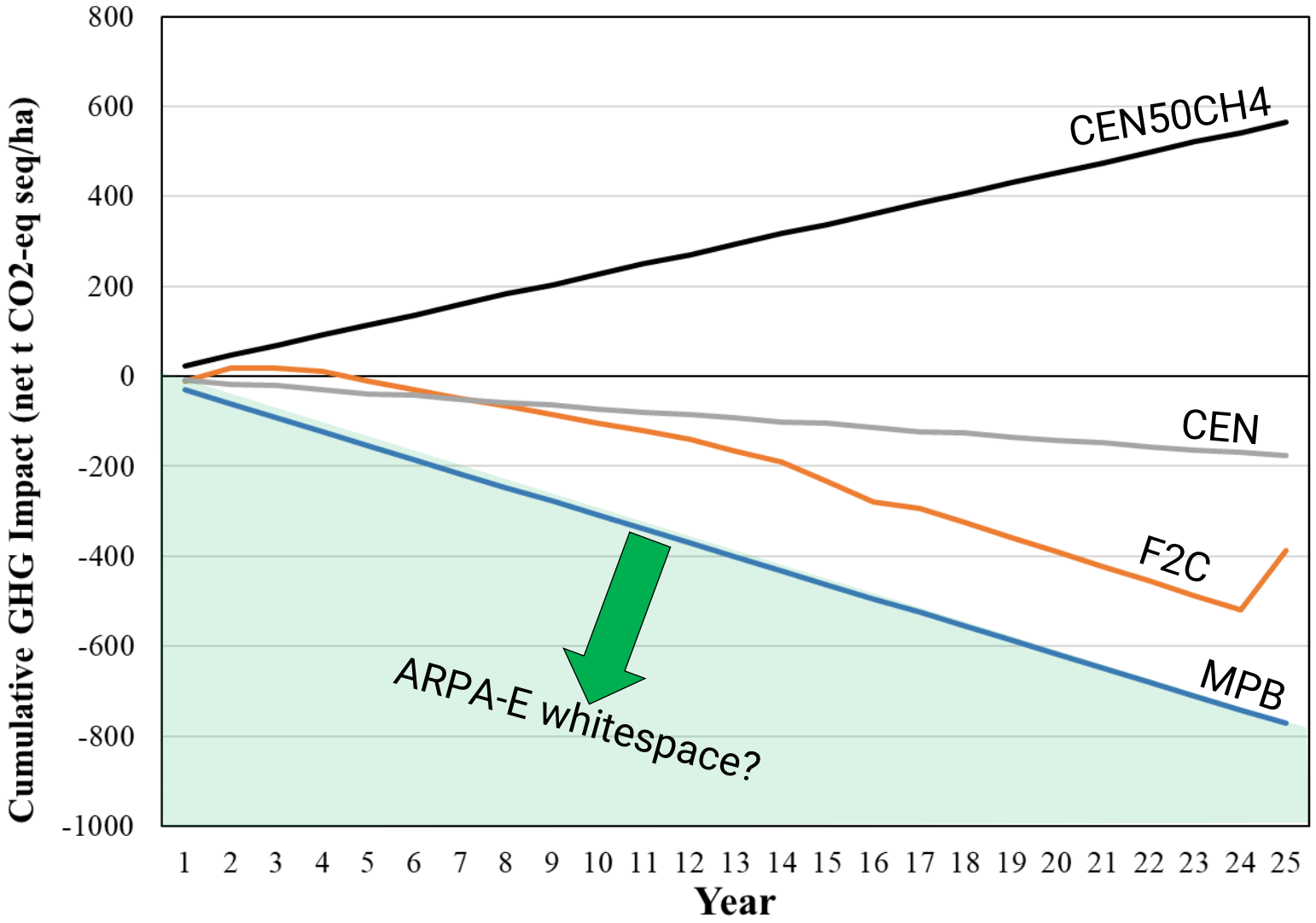
Carbon farming means tracking carbon flows, not product CI

= GHG flows that do not factor in bioethanol product C footprinting but must consider in C drawdown bioeconomy



CI = Carbon Intensity

New functional unit guides C farming metrics



CEN50CH4 = CENCH4 but C in DDGS, oil, soy go to CO2/CH4 mix and 50% stovers pyrolyzed and buried

CEN = Corn-Corn-Soy for bioethanol (C in DDGS, oil, soybean go to CO2) all stovers pyrolyzed and buried

F2C = Forestry to cross-laminated-timber

MPB = Miscanthus Py-oil Burying

Why are we here?

- **Identify high-risk, high-impact technologies** for low-cost carbon removal and management via nature-based terrestrial systems
- **Explore ways to optimize** the co-benefits of combined pathways, control for unintended consequences, and enhance ecosystem services
- **Identify economic drivers** for adoption, and assess the potential for scaling
- **Discuss the scope and technical targets** of a potential ARPA-E program (i.e., high risk, high impact)
- **Establish a community** of thought leaders to drive innovation in this space

Workshop Goal:

Identify high-risk, high-impact technologies for low-cost carbon removal and management

Genetics x Environment x Management

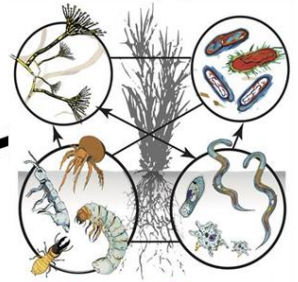
Parallel

Exclusive

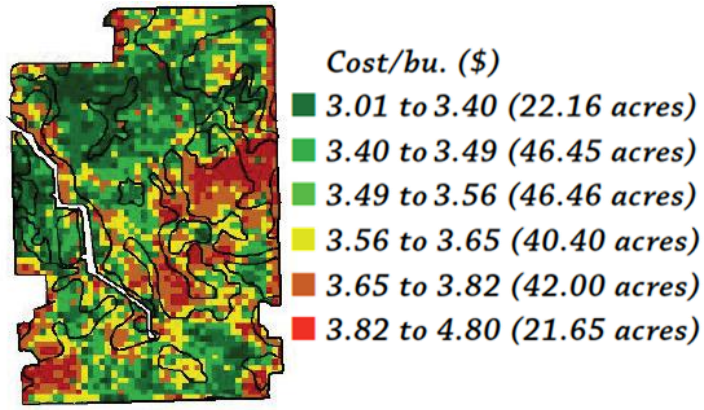
Plant engineering for biomass carbon optimization

Soil amendments

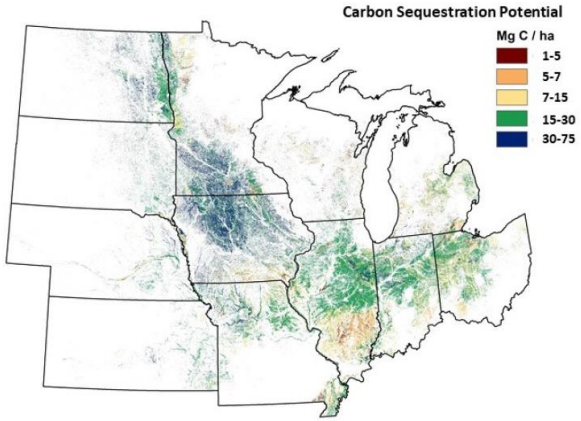
Rewiring the cover crop



Microbiome engineering



Management tools for system integration and decision support



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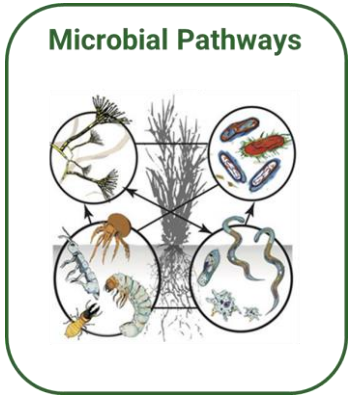
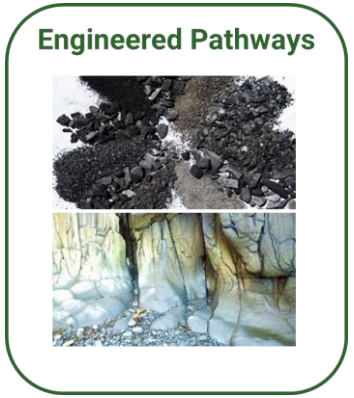
Workshop Goal:

Explore ways to optimize ecosystem synergies, and control for unintended consequences

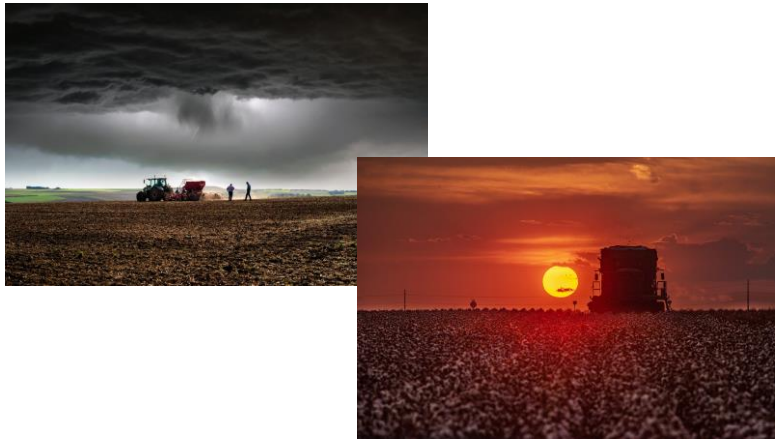
Co-Benefits





Trade-Offs

Climate Variability



Soil Variability

Ecosystem Services

Farm Operations

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Workshop Goal:

Identify economic drivers for adoption, and assess the potential for scaling

Carbon Farming Feedstock | Handling & Logistics | Conversion Tech | Product Scenarios

Parallel

Exclusive

	Hydrogen	Grid electricity	Liquid fuels	Biochar	RNG with capture	Renewable Nat'l Gas
Gasification	■	■	■			
Combustion		■				
Fast Pyrolysis	■	■	■	■		
Hydrothermal liquefaction			■	■		
Biogas utilization		■			■	■

BiCRS Roadmap

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Agenda

Day 1: Tuesday, June 28, 2022

Time (CT)	Topic
1:00 PM	**ARPA-E Welcome** *Dr. James Zahler, Associate Director for Technology-to-Market, ARPA-E*
1:10 PM	**Workshop Overview and Meeting Goals** *Dr. David Babson, Program Director, ARPA-E*
1:35 PM	**Participant Introductions** *30 Seconds Each*
2:20 PM	Break
2:35 PM	**Plant Pathways for Net Carbon Removal** *Dr. Wolfgang Busch, The Salk Institute*
2:55 PM	**Farming Carbon: How Plant Roots, Microbial Ecophysiology and Soil Minerals Shape the Fate and Persistence of Soil Carbon** *Dr. Jennifer Pett-Ridge, Lawrence Livermore National Laboratory*
3:15 PM	**Engineered Conversion and Stabilization Pathways for Biomass Carbon** *Dr. William (Joe) Sagues, North Carolina State University*
3:35 PM	Break, Transition to Breakout Rooms
3:45 PM	**Breakout Session 1: Carbon Farming Pathways** (*See attendee roster for breakout assignments*) • Room A: Feedstock Pathways • Room B: Microbial Pathways • Room C: Engineered Pathways • Room D: Emissions Avoidance Pathways
5:00 PM	Adjourn

Day 2: Wednesday, June 29, 2022

Time (CT)	Topic
8:00 AM	Breakfast
9:00 AM	**Welcome to Day 2** *Dr. David Babson, Program Director, ARPA-E*
9:10 AM	**Panel Discussion: Carbon Farming Dynamics** • *Dr. Edward Buckler, USDA* • *Dr. Kirsten Hofmockel, Pacific Northwest National Laboratory* • *Dr. Alison King, Colorado State University* • *Dr. Sharon Bard, Terra Economics* • *Moderated by Mr. Alan Weber, MARC-IV*
10:10 AM	**Breakout 2 Overview** *Dr. David Babson, Program Director, ARPA-E*
10:15 AM	Break, Transition to Breakout Rooms
10:40 AM	**Breakout Session 2: Carbon Farming Systems** (*See attendee roster for room assignments*)
12:00 PM	Lunch
1:00 PM	**Market Criteria for Carbon Farming Pathways** *Dr. Daniel Sanchez, Carbon Direct*
1:20 PM	**Ecosystem Service Opportunities in Agriculture: Are We Missing the Forest for the Trees?** *Dr. Nick Goeser, Tech-to-Market Advisor, ARPA-E*
1:40 PM	**Fireside Chat – Carbon Farming from the Grower's Perspective** • *Mr. Brandon Hunnicutt, Hunnicutt Farms* • *Mr. Matthew Rohlik, Glennoe Farmland Partners, LLC* • *Moderated by Mr. Nick Reinke, HabiTerre*
2:20 PM	**Breakout 3 Overview** *Dr. Nick Goeser, Tech-to-Market Advisor, ARPA-E*
2:30 PM	Break, Transition to Breakout Rooms
3:00 PM	**Breakout Session 3: Carbon Farming at Scale** (*See attendee roster for room assignments*)
4:30 PM	Adjourn

PARTICIPANT INTRODUCTIONS

- Name
- Organization
- What brings you to the workshop?